liquid crystal display elements having a air of substrates with a liquid crystal therebetween having a spontaneous polarization; and

an electrode corresponding to a pixel and a switching element that are placed on an inner surface of one of the substrates, the switching element being allowed to drive the liquid crystal corresponding to a pixel when turned on,

wherein the spontaneous polarization of the liquid crystal is a magnitude of not more than ½ of a quantity of charge that is injected into a liquid crystal element when a maximum driving voltage is applied to the liquid crystal element corresponding to a pixel when the switching element is turned on.

REMARKS

Claim 1 stands rejected under 35 U.S.C. 112, second paragraph, as being indefinite. Applicants respectfully traverse. Although Applicants do not agreed with the Examiners assertion that the term "maximum" is not properly disclosed in the Specification to the present Application, in the interest of expediting prosecution, claim 1 has been amended to more clearly define the relevant feature of the present invention. Reconsideration and withdrawal of this rejection, in light of this amendment, are respectfully requested.

Claim 1 stands rejected under 35 U.S.C. 102(b) as being anticipated by Toyoda (JP 05-34724). Applicants respectfully traverse this rejection because the cited reference

does not disclose (or suggest) that a spontaneous polarization of a liquid crystal is a magnitude of not more than ½ of a quantity of charge that is injected into a liquid crystal display element when a maximum driving voltage is applied to the liquid crystal element, as in claim 1 of the present invention, as amended.

In the interest of expediting prosecution and furthering this discussion, a complete English translation of the Toyoda reference is provided with this Amendment. As can be seen throughout the reference, Toyoda only discloses that the accumulated value (sum) of electric charge for all of the TFTs is greater than or equal to twice the spontaneous polarization of the liquid crystal. It can be seen from the complete reference that this accumulated charge, or sum of capacity, is not the same as the quantity of charge injected into a liquid crystal element when a maximum driving voltage is applied to the liquid crystal. According to Toyoda, the value of accumulated charge in the entire capacity must always be greater than or equal to the value of spontaneous polarization.

In contrast, in claim 1 of the present invention has been amended to more clearly recite, among other things, that the quantity of charge injected into a liquid crystal element when a maximum driving voltage is applied to the liquid crystal element is greater than or equal to the quantity of spontaneous polarization. This quantity of injected charge at maximum driving voltage is therefore the "maximum quantity of charge" applied to the liquid crystal, and not the same as a mere accumulation of capacity that maybe found for any particular quantity of charge. In other words, in the present invention, because only the

maximum quantity of charge need be greater than twice the spontaneous polarization, a quantity of injected charge which is less than maximum can be less than twice the spontaneous polarization. Toyoda teaches that such result are impossible. Accordingly, claim 1 of the present invention is different than Toyoda, and the Section 102 rejection based on Toyoda is respectfully traversed.

The difference between the present invention and Toyoda is further illustrated by the fact that a spontaneous polarization value for a liquid crystal is invariable. It is inherent to each particular material. The injected quantity of charge to a liquid crystal, on the other hand, will vary according to the applied voltage. The "maximum quantity of charge" therefore, will achieve the maximum spontaneous polarization response, and the greatest value of light transmittance from a liquid crystal display element. When a charge smaller than this maximum quantity is applied to the liquid crystal, however, spontaneous polarization response will also be smaller, and light transmittance will only achieve intermediate levels (i.e., half-tone displays, etc.). Toyoda defines the relationship between spontaneous polarization and voltage according to such lower voltage, half-tone displays, whereas the present invention features a spontaneous polarization relationship only with the maximum charge, and full light transmittance.

Moreover, Toyoda teaches the use of a binary (monotone) display. The present invention on the other hand, features a gradation display which includes optical half-tone display. Accordingly, in the present invention, when a voltage for driving the liquid crystal is

low (less than maximum), the quantity of injected charge applied to the liquid crystal may be smaller than twice the value of spontaneous polarization. Toyoda could not achieve such a result, as its device requires that the quantity of injected charge always be greater than or equal to twice the value of spontaneous polarization. For at least these additional reasons, the Section 102 rejection of claim 1 based on Toyoda is further traversed.

Claims 2, 5-6, 9-10, and 13-14 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Toyoda in view of Koden et al. (U.S. 5,465,168). Applicants respectfully traverse this rejection for at least the reasons discussed above in traversing the rejection of independent claim 1. Claims 2, 5-6, 9-10, and 13-14 all depend either directly or indirectly from claim 1 of the present invention, and therefore include all of the features of the base claim, plus additional features. Applicants further traverse as follows.

As discussed above, the present invention realizes a specific advantages over the device taught by Toyoda. According to Toyoda, the quantity of injected charge must always be greater than or equal to twice the spontaneous polarization value. In the present invention, however, the quantity of injected charge may be advantageously less than twice the spontaneous polarization value. Toyoda therefore could not form the basis of an obviousness rejection, where the present invention realizes with such significant advantageous results over Toyoda.

Koden is cited by the Examiner merely for teaching when a ferroelectric liquid crystal material having a large spontaneous polarization is used, a dielectric constant varies

depending on the frequency of the alternating voltage, and the resultant value of spontaneous polarization. Such features have nothing to do with the value of spontaneous polarization based on driving voltages, and/or quantity of charge, injected into the liquid crystal element. More particularly, Koden remains silent regarding maximum quantity of charge, or the quantity of charge injected when a maximum driving voltage is applied. Accordingly, for at least these reasons, the Section 103 rejection based on a combination of Toyoda and Koden is respectfully traversed.

Claims 3, 7, 11, and 15 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Toyoda in view of Okada et al. (U.S. 6,177,968). Applicants respectfully traverse this rejection for at least the reasons discussed above in traversing the rejection of independent claim 1. Claims 3, 7, 11, and 15 all depend indirectly on claim 1, and therefore include all of the features of the base claim, plus additional features. Okada is cited merely for teaching color filters. Okada remains silent about the relationship of spontaneous polarization with driving voltage and quantity of charge.

Attached hereto is a marked-up version of the changes made to the claim by the current Amendment. The attached page is captioned **"Version with Markings to Show Changes Made.**

For all of the foregoing reasons, Applicants submit that this Application, including claim 1-16 is in condition for allowance, which is respectfully respected. The Examiner is invited to contact the undersigned Attorney if an interview would expedite prosecution.

Respectfully submitted

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Version with Markings to Show Changes Made

Please amend claim 1 as follows:

1. (Amended) A liquid crystal display, comprising:

liquid crystal display elements having a air of substrates with a liquid crystal therebetween having a spontaneous polarization; and

an electrode corresponding to a pixel and a switching element that are placed on an inner surface of one of the substrates, the switching element being allowed to drive the liquid crystal corresponding to a pixel when turned on,

wherein the spontaneous polarization of the liquid crystal is a magnitude of not more than ½ of a ~~maximum~~ quantity of charge that is injected ~~to the~~ into a liquid crystal ~~display~~ element when a maximum driving voltage is applied to the liquid crystal element corresponding to a pixel when the switching element is turned on.

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[Title of the Invention] Ferroelectric Liquid Crystal Cell

[Abstract]

[Object] The ferroelectric liquid crystal cell eliminates unfavorable influence of reversal current generated when a liquid crystal cell composed of a ferroelectric liquid crystal and thin-film transistors (TFTs) is operated.

[Constitution] The value of electric charge accumulated in the capacity of a TFT on the drain electrode side is made to be equal to or larger than twice the product of a spontaneous polarization of a ferroelectrics liquid crystal and the area of pixel electrodes.

[Claims for Patent]

[Claim 1] A ferroelectrics liquid crystal cell comprising a liquid crystal cell sandwiched between: a TFT array substrate having TFTs and pixel electrodes on a substrate at least a surface of which is made of insulator; and a counter substrate having counter electrodes on a substrate at least a surface of which is made of insulator, wherein a value of electric charge accumulated in an entire capacity of the TFTs on a drain electrode side is made to be equal to or larger than twice the product of a spontaneous polarization of a ferroelectrics liquid crystal and the area of pixel electrodes.

[Detailed Description of the Invention]

[0001]

[Field of Industrial Application] The present invention relates to a ferroelectric liquid crystal cell to be used, for example, for a liquid crystal spatial light modulator or a liquid crystal display.

[0002]

[Prior Art] FIG. 4 is a sectional view showing the constitution of a conventional liquid crystal cell disclosed in Japanese Patent Application Laid-open No. 62-299064 (1987) and FIG. 5 is a circuit diagram of the same. In FIG. 4, reference numeral 20 denotes a TFT array substrate, 4 denotes a transparent insulation substrate, 5 denotes a pixel electrode for which an ITO is generally used, 6 denotes a gate wiring, 7 denotes a semiconductor layer, 8 denotes a source wiring, 9 denotes a drain electrode, 10 denotes a gate insulation film, 11 denotes a protection film formed of a insulation film such as a silicon-nitride film, and 12 denotes an orientation film. Numeral 2 denotes a counter substrate, 13 denotes a transparent insulating substrate, 14 denotes a counter electrode for which an ITO is generally used, and 15 denotes an orientation film. The counter electrode 14 is connected to a common electrode. Numeral 3 denotes a liquid crystal sandwiched between the TFT array substrate and the counter substrate.

[0003] Next, operations will be described. When a voltage is applied to the gate electrode, a carrier is induced to the semiconductor layer and the TFT is turned on, whereas the TFT is in an OFF state when no voltage is applied. In the ON state, a source signal voltage is applied to the drain electrode as it is, so that a voltage equal to the difference between the source signal voltage and a voltage applied to the counter electrode on the counter substrate is applied to the liquid crystal.

[0004] A molecule axis of ferroelectric liquid crystal can be oriented in two

directions. When a voltage is applied, the direction of the molecule axis changes from one direction to another. Moreover, the ferroelectric liquid crystal has anisotropy in refractive index, and hence, with an arrangement in which a polarizer is provided before and after the ferroelectric liquid crystal so that the polarizing direction of the polarizer is straight ahead and the polarizing direction of a polarizer on the incident side agrees with the molecule axis of either one of the two directions of the molecule axis, light can be turned on/off by applying a voltage.

[0005] When the molecule axis of the ferroelectric liquid crystal changes, a reversal current caused by a spontaneous polarization flows. The total amount of electric charge of the reversal current is in proportion to the value of the spontaneous polarization.

[0006]

[Problem to Be Solved by the Invention] The conventional liquid crystal cell is constructed as described above. Since no consideration is given to a value of load capacity for accumulating electric charge of reversal current of ferroelectric liquid crystal, in the case of a liquid crystal cell which uses a ferroelectric liquid crystal having a large spontaneous polarization, there arises a problem, for example, that electric charge of reversal current is not accumulated and normal operation is hampered.

[0007] The present invention is made to solve the above problems, and an object of the invention is to provide an apparatus which is capable of normal operation even if a liquid crystal having a large spontaneous polarization is used in it.

[0008]

[Means for Solving the Problems] The present invention relates to a

ferroelectric liquid crystal cell comprising a liquid crystal cell sandwiched between: a TFT array substrate having TFTs and pixel electrodes on a substrate at least a surface of which is made of insulator; and a counter substrate having counter electrodes on a substrate at least a surface of which is made of insulator, wherein a value of electric charge accumulated in an entire capacity of the TFTs on a drain electrode side is made to be equal to or larger than twice the product of a spontaneous polarization of a ferroelectrics liquid crystal and the area of pixel electrodes.

[0009]

[Operation] A ferroelectric liquid crystal cell of the present invention ensures normal operations of a ferroelectric liquid crystal having a large spontaneous polarization by making the value of electric charge accumulated in the entire capacity of TFTs on the drain electrode side equal to or larger than twice the product of a spontaneous polarization of a ferroelectrics liquid crystal and the area of pixel electrodes.

[0010]

[Embodiment] An embodiment of the present invention will be described below with reference to FIG. 1 and FIG. 2. In FIG. 1, reference numeral 1 denotes a TFT array substrate, 4 denotes a transparent insulation substrate, 5 denotes a pixel electrode (transparent electrode) such as an ITO, 6 denotes a gate wiring, 7 denotes a semiconductor layer, 8 denotes a source wiring, 9 denotes a drain electrode, 10 denotes a gate insulation film, 11 denotes a protection film formed of a insulation film such as a silicon-nitride film, 12 denotes an orientation film and 16 denotes a grounding electrode.

[0011] The material, shape or the like of the aforementioned gate wiring, semiconductor layer, source wiring, drain electrode, gate insulation film,

protection film, orientation film and a grounding electrode has no limitation, as long as the value of load capacity on the drain side electrode satisfies the following requirements.

[0012] In other words, in a cell of the present invention, the value of electric charge accumulated in the entire capacity of a TFT on the drain electrode side is made to be equal to or larger than twice the product of a spontaneous polarization of a ferroelectrics liquid crystal and the area of pixel electrodes in order to accumulate an electric charge for a reversal current. To be more specific, the pixel electrode refers to a pixel electrode provided on a transistor array substrate, and the area refers to the area of a portion in which the ferroelectric liquid crystal is reversed.

[0013] The capacity on the drain electrode side is formed of: a capacity between a pixel electrode of a TFT array substrate and a counter electrode of a counter substrate; a capacity between a drain electrode of a TFT array substrate and a counter electrode of a counter substrate; a capacity between a gate electrode and a drain electrode; a capacity between a source electrode and a drain electrode; and an accumulated capacity, such as a capacity between a drain electrode and a grounding electrode, a capacity between a pixel electrode and a ground electrode.

[0014] According to the example shown in FIG. 1, the accumulated capacity is formed of sandwiching the gate insulation film 10 between the grounding electrode 16 and the pixel electrode 5. A value of the accumulated capacity is determined so that the sum of the accumulated capacity and the charge amount accumulated in other capacities on the drain electrode side is equal to or larger than twice the product of a spontaneous polarization of the ferroelectrics liquid crystal and the area of the pixel electrodes. Although

the example shown in FIG. 1 uses the gate insulation film 10 as an insulation film for the accumulated capacity, an insulation film 17 may be formed separately as shown in FIG. 3. Further, the accumulated capacity may be formed between the drain electrode and the gate electrode.

[0015] Moreover, as an alternative method for increasing the capacity on the drain electrode side, a method of narrowing a cell gap may be adopted. This may be adopted together with the method using the accumulated capacity.

[0016] In FIG. 1, reference numeral 2 denotes a counter substrate, and 13 denotes a transparent insulation substrate, 14 denotes a counter electrode (transparent electrode) and 15 denotes an orientation film. The counter electrode 14 is connected to a common electrode. The material, shape or the like of the transparent insulation substrate, counter electrode and orientation film is not limited, similarly to the above described TFT array substrate.

[0017] Reference numeral 3 denotes a liquid crystal sandwiched between the two substrates. The liquid crystal desirably has a large spontaneous polarization which permits high-speed operations. An accumulated capacity is needed when a ferroelectric liquid crystal having a spontaneous polarization of not less than $6.6nc/cm^2$ is used.

[0018] Next, a ferroelectric liquid crystal cell of the present invention will be described in more specific terms on the basis of an embodiment of the invention.

[0019] [Embodiment1] As an example of a liquid crystal cell of the present invention, an embodiment of a cell having a section as shown in FIG. 3 will be described.

[0020] The liquid crystal adopted in the embodiment is CS-1024

manufactured by CHISSO Corporation, which has a spontaneous polarization of 35nm/ cm^2. This liquid crystal is sandwiched between a TFT array substrate and a counter substrate. In this case, the distance between the counter electrode and the pixel electrode is set to 2.5 μm including the thickness of the protection film. The area of the pixel electrode is 1.6×10^{-5} cm^2.

The capacity between the pixel electrode and the counter electrode is 270 fF, the capacity between the drain electrode and the counter electrode is 18fF, the capacity between the gate electrode and the drain electrode is 74fF, the capacity between the source electrode and the drain electrode is 12fF, and the accumulated capacity is 74fF. Note that a voltage of 10 volt is applied to the storage capacity, and the operation voltage of the liquid crystal is also 10 volt.

[0021] FIG. 6 shows operation results of the cell with the above construction.

[0022]

[Advantages of the Invention] As described above, according to the present invention, the value of electric charge accumulated in the entire capacity of the TFTs on the drain electrode side is made to be equal to or larger than twice the product of a spontaneous polarization of the ferroelectrics liquid crystal and the area of the pixel electrodes, and hence, a liquid crystal cell using a ferroelectric liquid crystal having a large spontaneous polarization can be operated normally.

[Detailed Description of the Drawings]

[FIG. 1] A sectional view of a liquid crystal cell according to an embodiment of the present invention

[FIG. 2] A circuit diagram of the liquid crystal cell shown in FIG. 1.

[FIG. 3] A sectional view of a liquid crystal cell according to an embodiment of the present invention

[FIG. 4] A sectional view of a prior art liquid crystal cell.

[FIG. 5] A circuit diagram of the liquid crystal shown in FIG. 4

[FIG. 6] A graph showing operation results of a liquid crystal cell according to Embodiment 1

[Description of Reference Numerals]

1	TFT Array Substrate
2	Counter Substrate
3	Liquid Crystal
4, 13	Transparent Insulation Film
5	Pixel Electrode
6	Gate Wiring
7	Semiconductor Layer
8	Source Wiring
9	Drain Electrode
10	Gate Insulation Film
14	Counter Electrode
16	Grounding Electrode
17	Insulation Film For Accumulated Capacity